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Thermal Casimir and Casimir-Polder interactions in N parallel 2D Dirac materials

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Abstract

© 2018 IOP Publishing Ltd. The Casimir and Casimir-Polder interactions are investigated in a stack of equally spaced graphene layers. The optical response of the individual graphene is taken into account using gauge invariant components of the polarization tensor extended to the whole complex frequency plane. The planar symmetry for the electromagnetic boundary conditions is further used to obtain explicit forms for the Casimir energy stored in the stack and the Casimir-Polder energy between an atom above the stack. Our calculations show that these fluctuation induced interactions experience strong thermal effects due to the graphene Dirac-like energy spectrum. The spatial dispersion and temperature dependence in the optical response are also found to be important for enhancing the interactions especially at smaller separations. Analytical expressions for low and high temperature limits and their comparison with corresponding expressions for an infinitely conducting planar stack are further used to expand our understanding of Casimir and Casimir-Polder energies in Dirac materials. Our results may be useful to experimentalists as new ways to probe thermal effects at the nanoscale in such universal interactions.

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Keywords

Casimir effect, Casimir-Polder interaction, grapheme

References

[1] Casimir H 1948 Kon. Ned. Akad. Wetensch. Proc. 51 793-5

[2] Casimir H B G and Polder D 1948 Phys. Rev. 73 360-72

[3] Lifshitz E M 1956 Sov. Phys. - JETP 2 329-49

[4] Woods L M, Dalvit D A R, Tkatchenko A, Rodriguez-Lopez P, Rodriguez A W and Podgornik R 2016 Rev. Mod. Phys. 88 45003

[5] Klimchitskaya G L, Mohideen U and Mostepanenko V M 2009 Rev. Mod. Phys. 81 1827-85

[6] Nimmrichter S and Hornberger K 2008 Phys. Rev. A 78 023612

[7] Gerlich S et al 2007 Nat. Phys. 3 711-5

[8] Leanhardt A E, Shin Y, Chikkatur A P, Kielpinski D, Ketterle W and Pritchard D E 2003 Phys. Rev. Lett. 90 100404

[9] Druzhinina V and DeKieviet M 2002 Phys. Rev. Lett. 91 193202

[10] Chan H B, Aksyuk V A, Kleiman R N, Bishop D J and Capasso F 2001 Science 291 1941-4

[11] Buks E and Roukes M L 2001 Phys. Rev. B 63 033402

[12] Esquivel-Sirvent R, Cocoletzi G H and Palomino-Ovando M 2010 J. Appl. Phys. 108 114101
[13] Drosdoff D and Woods L M 2014 Phys. Rev. Lett. 112 025501
[14] Popescu A, Woods L M and Bondarev I V 2011 Phys. Rev. B 83 081406
[15] Bordag M, Geyer B, Klimchitskaya G L and Mostepanenko V M 2006 Phys. Rev. B 74 205431
[16] Sarabadani J, Naji A, Asgari R and Podgornik R 2011 Phys. Rev. B 84 155407
[17] Gómez-Santos G 2009 Phys. Rev. B 80 245424
[18] Rodriguez-Lopez P, Kort-Kamp W J M, Dalvit D A R and Woods L M 2017 Nat. Commun. 8 14699
[19] Sushkov A O, Kim W J, Dalvit D A R and Lamoreaux S K 2011 Nat. Phys. 7 230-3
[20] Bimonte G, Klimchitskaya G L and Mostepanenko V M 2017 Phys. Rev. A 96 012517
[21] Bordag M, Klimchitskaya G L, Mostepanenko V M and Petrov V M 2015 Phys. Rev. D 91 45037
[22] Klimchitskaya G L and Mostepanenko V M 2016 Phys. Rev. B 93 245419
[23] Rodriguez-Lopez P, Kort-Kamp W J M, Dalvit D A R and Woods L M 2018 Phys. Rev. Mater. 2 014003
[24] Klimchitskaya G L and Mostepanenko V M 2015 Phys. Rev. B 91 174501
[25] Kuzmenko A B, Van Heumen E, Carbone F and Van Der Marel D 2008 Phys. Rev. Lett. 100 117401
[26] Drosdoff D and Woods L M 2010 Phys. Rev. B 82 155459
[27] Fialkovsky I and Vassilevich D 2012 Eur. Phys. J. B 85 384
[28] Bordag M, Fialkovsky I V, Gitman D M and Vassilevich D V 2009 Phys. Rev. B 80 245406
[29] Fialkovsky I V, Marachevsky V N and Vassilevich D V 2011 Phys. Rev. B 84 35446
[30] Bordag M, Fialkovskiy I and Vassilevich D 2016 Phys. Rev. B 93 75414
[31] Bordag M, Fialkovskiy I and Vassilevich D 2017 Phys. Rev. B 95 119905
[32] Gusynin V P, Sharapov S G and Carbotte J P 2007 J. Phys.: Condens. Matter 19 26222
[33] Falkovsky L A and Varlamov A A 2007 Eur. Phys. J. B 56 281-4
[34] Khusnutdinov N, Kashapov R and Woods L M 2016 Phys. Rev. A 94 012513
[35] Khusnutdinov N, Kashapov R and Woods L M 2015 Phys. Rev. D 92 045002
[36] Kashapov R, Khusnutdinov N and Woods L M 2016 Int. J. Mod. Phys. A 31 1641028
[37] Bordag M, Klimchitskaya G L, Mohideen U and Mostepanenko V M 2009 Advances in the Casimir Effect (New York: Oxford University Press) p 745
[38] Bezerra V B, Klimchitskaya G L, Mostepanenko V M and Romero C 2008 Phys. Rev. A 78 42901